TERRESTRIAL ENERGY USA

Commercial Deployment of TEUSA's Innovative Gen IV Integral Molten Salt Reactor

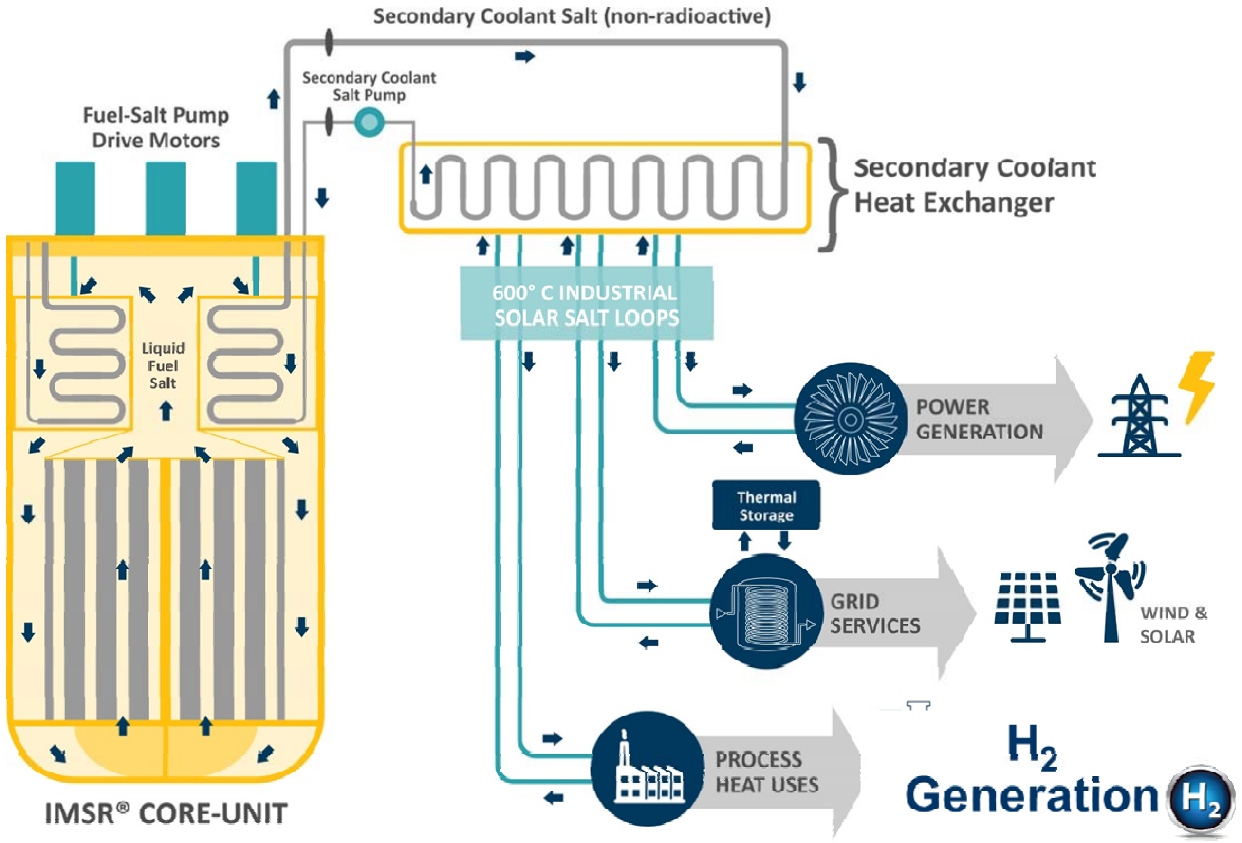
"Restoring America's Nuclear Competitive Edge with the Cost Competitive and Highly Reliable IMSR® 400"

31 October 2018

MSR Integration

TERRESTRIAL ENERGY USA

Integration of Hydrogen Generation with an Integral Salt Reactor IMSR®



THE PROGRAM OBJECTIVES:

- System Analysis
  - Develop a plausible path to hydrogen production cost less than \$2/kgH_2 based on the process design and cost estimation.
  - Develop a conceptual plant design for MSR-HyS
  - Develop a techno-economic analysis of H_2 production via MSR-HyS
  - The HyS process, being a two step process, can act as a buffer and store thermal energy chemically as liquid SO_2, to be used to generate hydrogen as required to minimize generation and storage costs

HyS CHEMISTRY

- Hybrid Sulfur (HyS) is a two-step thermo-chemical cycle based on sulfur oxidation/reduction
- Key Reaction Step is electro-chemical water splitting using an SO_2 depolarized electrolyzer (SDE)
- All fluid processing minimizes entropic losses due to phase changes

$H_2SO_4 \rightarrow H_2O + SO_2 + {}^1/_2\, O_2$ **Thermochemical:** 600-900°C

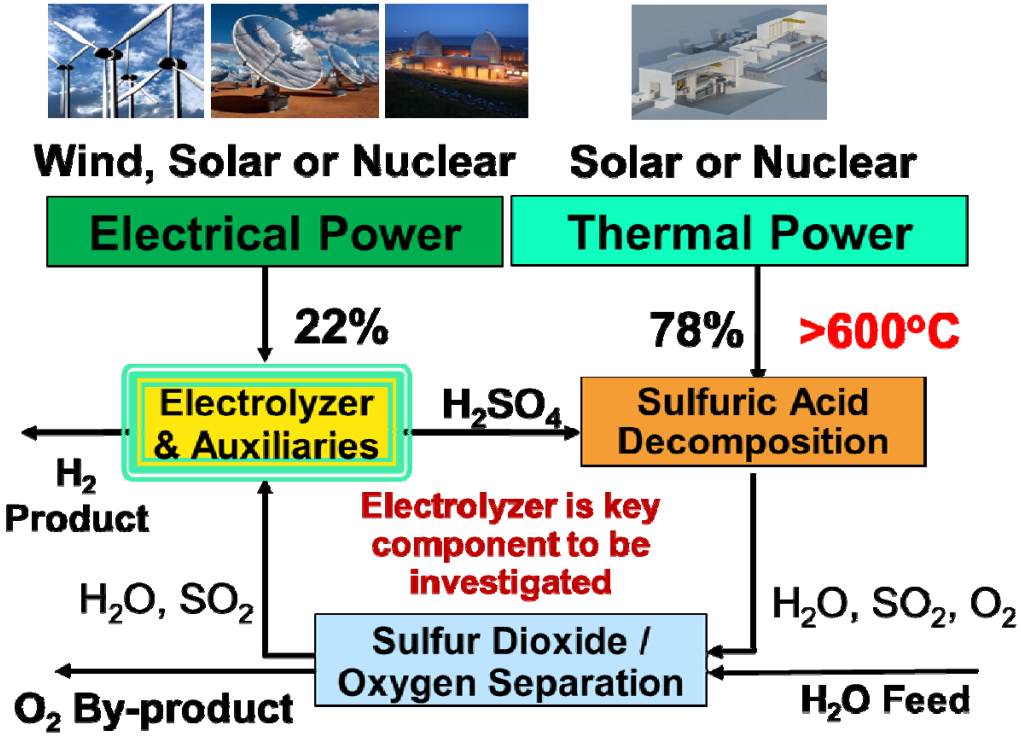
$SO_2 + 2\, H_2O \leftrightarrow H_2SO_4 + H_2$ **Electrochemical:**

0.17 v_{th} (~0.5v_{pr}) 80-140°C

$H_2O \rightarrow H_2 + {}^1/_2\, O_2$ **Net Reaction**

HyS System Overview

- HyS is "hybrid" cycle requiring electrical and thermal energy input
- Optimization of the system requires trade-offs between the various components



CONCLUSION

The Cheapest Hydrogen from Steam Reformation in the Gulf of Mexico Louisiana today is about $3.00 Kg and is tied to the Volatile cost of Natural Gas

IMSR HyS Hydrogen shows strong positive evidence of being less than $2.00 per Kg
And as economy of scale, better Membranes, and improved IMSR's are produced
– we see H2 declining much below $2.00 Kg
- IMSR H2 can be made for same price anywhere , especially where it is needed in Midwest USA

While exports and more realistic production estimates show Natural Gas rising in cost

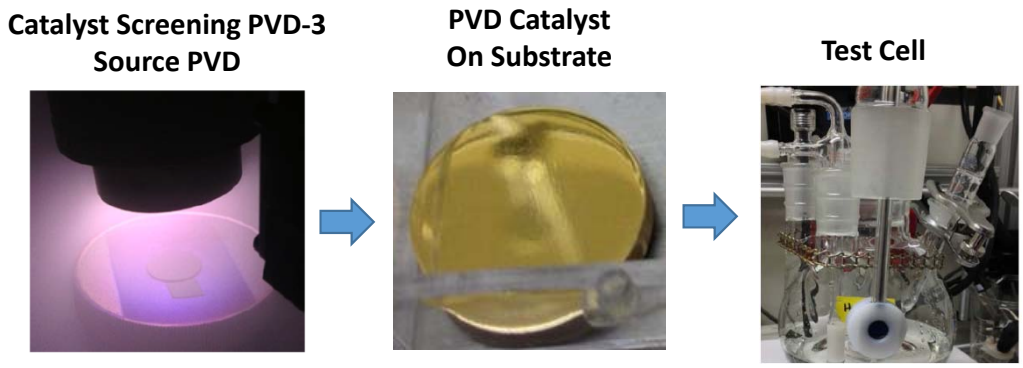
Terrestrial needs this account to justify its purpose – decarbonize not just the 30% electric market
But that IMSR is the way to decarbonize the 70% of carbon from transportation, and process heat

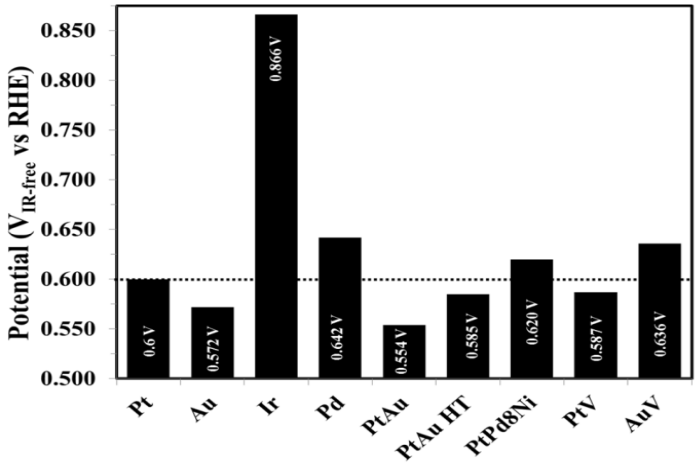
IMSR is the Tool that Unlocks Vast Opportunities

The IMSR is the type of Generation 4 Reactor project that will keep the U.S.A. the leader in Industry, and make our economy clean, safe, and prosperous for the people of the United States of America.

- Terrestrial Energy USA Inc.
  - John Kutsch
    - T: +1 (312) 303 5019
    - E: jkutsch@TerrestrialUSA.com
    - www.TerrestrialUSA.com

MULTI-METAL ELECTRO-CATALYSTS

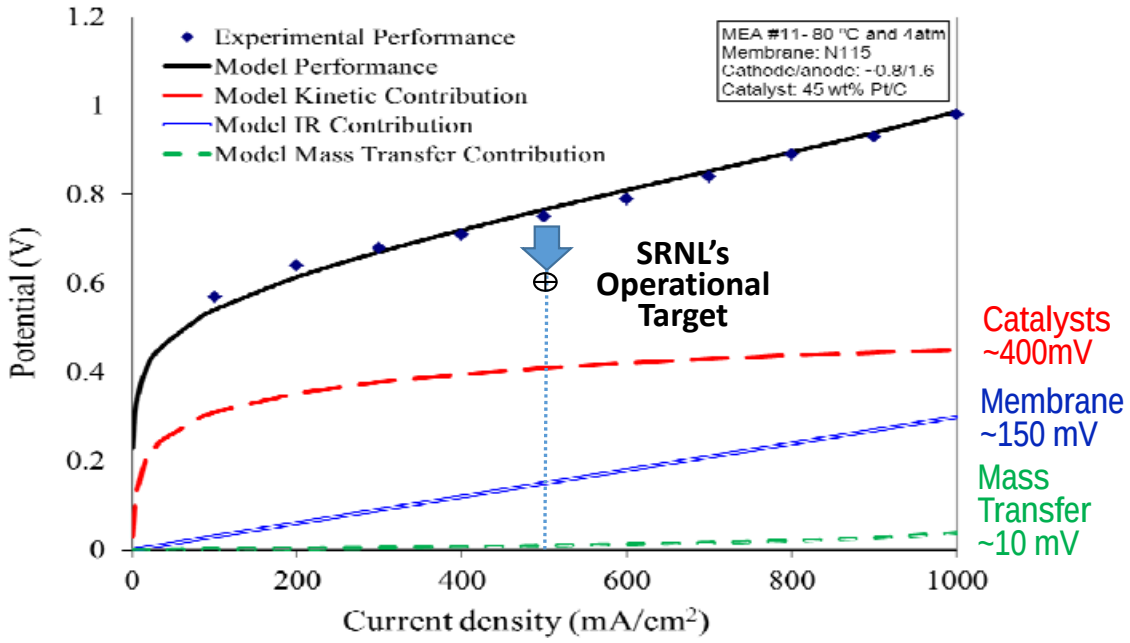




- Previous electrocatalyst developments required individually sputtered compositions, and evaluation in electrochemical cell
- Au, $Pt_{0.5}Au_{0.5}$ and $Pt_{0.5}V_{0.5}$ compositions have been identified as superior to Pt alone
- Full compositional range of $Pt_xAu_yV_z$ (for x+y+z=1) need to be investigated to identify optimum catalytic activity
- Additional transition metal (Tm) compositions (i.e. $Pt_xAu_yTm_z$) need to be investigated to identify potential alternate ternary compositions of interest.
- A combinatorial methodology needs to be identified to cover this large compositional space.

New MEMBRANE PERFORMANCE TARGETS

- New high temperature membranes having minimal SO_2 permeability and durability in SO_2/SO_3 environment required.
- New catalysts and supports resulting in 600mV potential at
- 500mA/cm2 required
- Membrane Electrode Assembly (MEA) required having >10%degradation in potential after 700 hrs. operation.

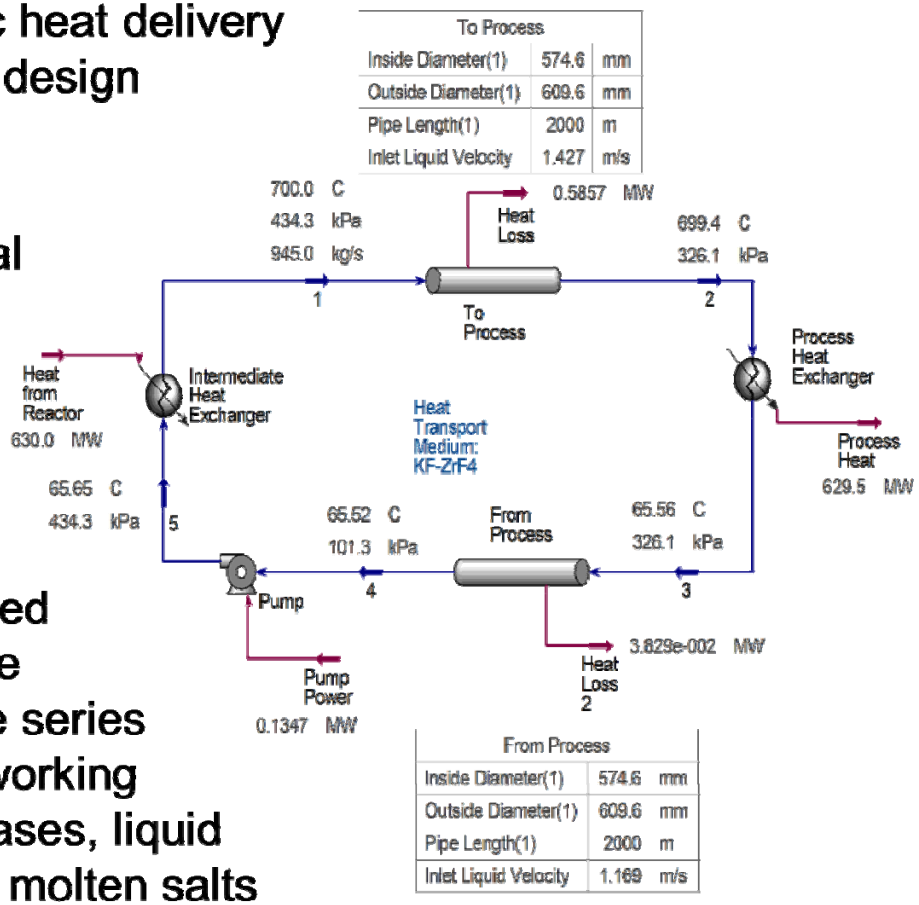


Kinetics (catalyst)
- ↑ Operating temperature
- ↑ Intrinsic higher activity

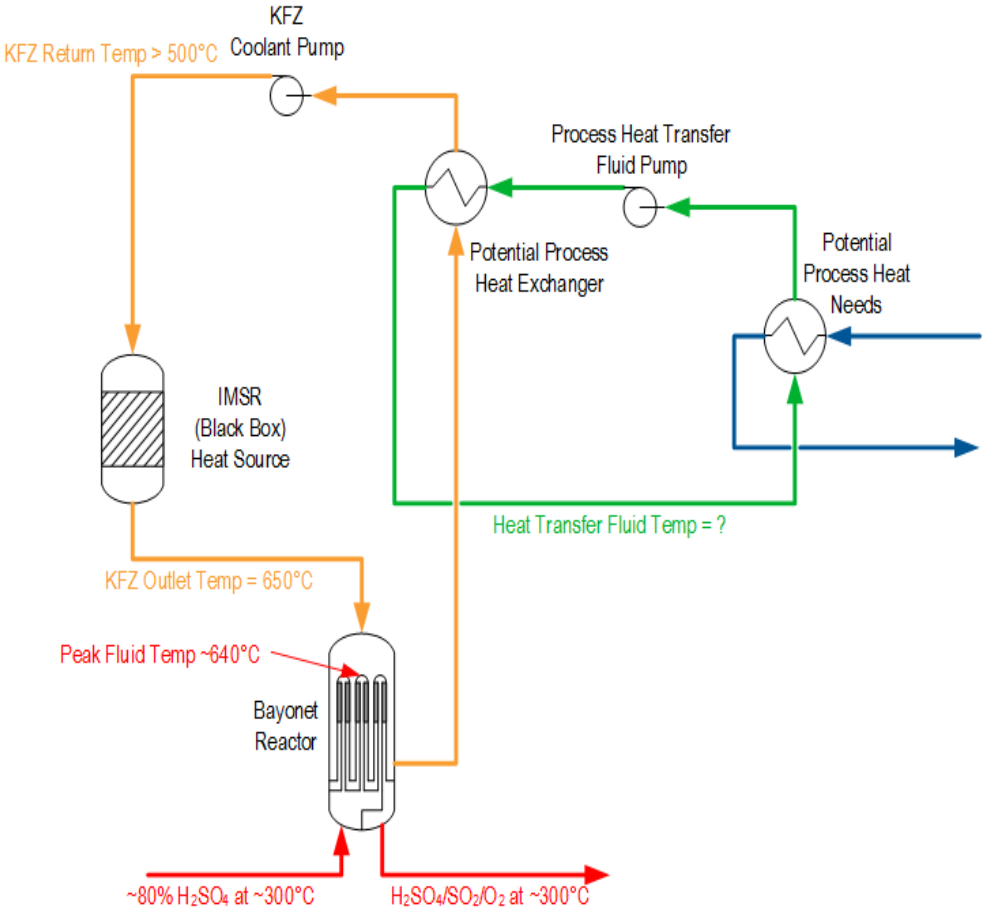
Cell resistance (membrane)
- ↑ Operating temperature
- ↑ ionic conductivity

SYSTEM ANALYSIS
NUCLEAR THERMAL HEAT TRANSFER

1. Design thermal hydraulic heat delivery system in HYSYS pump design specifications
2. Develop RELAP5-3D module to assess thermal energy delivery system from TEUSA Molten
3. Salt Reactors to HyS process
4. The RELAP5 series of codes has been developed at INL; RELAP5-3D is the latest code version in the series including more than 25 working fluids including water, gases, liquid metals, refrigerants, and molten salts



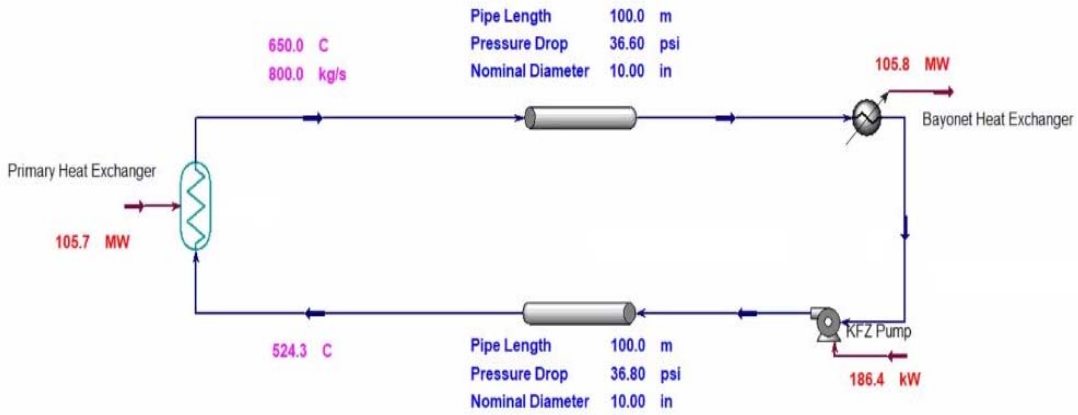
This work Started with HTGR Helium at 800c.
IMSR more than makes up for Lower heat with excellent salt properties and simplicity of salt Vs Helium



SRNL

Thermal Loop

- KFZ Properties from Literature
- Represents 1 Primary Heat Exchanger



INL